TABLE 1

Predictions of active material uptake using correlation and using full 1-D model

rib (micron)	groove depth (micron)	height/depth	contact angle (deg)	f area	correlation active material uptake (mg/in^2)	full model active material uptake (mg/in^2)	difference (mg/in^2)
50	25	0.5	10	0.20	0.43	0.27	0.16
50	25	0.5	45	0.20	0.33	0.30	0.03
50	25	0.5	80	0.20	0.23	0.32	−0.09
50	25	1	10	0.33	0.59	0.37	0.22
50	25	1	45	0.33	0.50	0.46	0.04
50	25	1	80	0.33	0.41	0.52	−0.11
50	25	2	10	0.50	0.50	0.30	0.20
50	25	2	45	0.50	0.60	0.58	0.02
50	25	2	80	0.50	0.69	0.76	−0.07
50	125	0.5	10	0.56	2.80	3.77	−0.97
50	125	0.5	45	0.56	4.03	4.16	−0.14
50	125	0.5	80	0.56	5.25	4.42	0.83
50	125	1	10	0.71	3.03	3.77	−0.74
50	125	1	45	0.71	4.76	4.94	−0.18
50	125	1	80	0.71	6.49	5.59	0.90
50	125	2	10	0.83	2.18	2.46	−0.28
50	125	2	45	0.83	4.59	4.80	−0.21
50	125	2	80	0.83	7.00	6.32	0.67
50	125	3	45	0.88	3.84	4.05	−0.21
50	125	5	80	0.93	5.83	6.29	−0.46
250	25	0.5	10	0.05	0.10	0.06	0.04
250	25	0.5	45	0.05	0.08	0.07	0.01
250	25	0.5	80	0.05	0.06	0.08	−0.02
250	25	1	10	0.09	0.16	0.10	0.06
250	25	1	45	0.09	0.14	0.13	0.01
250	25	1	80	0.09	0.11	0.14	−0.03
250	25	2	10	0.17	0.17	0.10	0.07
250	25	2	45	0.17	0.20	0.19	0.01
250	25	2	80	0.17	0.23	0.25	−0.02
250	125	0.5	10	0.20	1.01	1.36	−0.35
250	125	0.5	45	0.20	1.45	1.50	−0.05
250	125	0.5	80	0.20	1.89	1.59	0.30
250	125	1	10	0.33	1.41	1.76	−0.35
250	125	1	45	0.33	2.22	2.30	−0.08
250	125	1	80	0.33	3.03	2.61	0.42
250	125	2	10	0.50	1.31	1.48	−0.17
250	125	2	45	0.50	2.75	2.88	−0.12
250	125	2	80	0.50	4.20	3.79	0.40

[0237] By comparison, the anticipated uptake on the walls of the microchannel in the absence of the capillary features based entirely on a fill-and-drain process is less than 0.1 mg/in^2. Thus many washcoating steps are necessitated to gain high loadings and where the non-uniformity bias is retained on each washcoating step.

[0238] When the depth of the liquid was predicted to be less than the depth of the groove at any point in the groove, the model limits were exceeded and may not be valid. In the range simulated for the mathematical model, the contact angle and height to depth ratio were the only significant factors in determining whether the model limits were exceeded, which occurred near groove width to depth ratios of 2.3 and 4.5 for contact angles of 10 and 45 degrees, respectively. Under some conditions, the liquid retention per groove was significant for groove depths and/or widths as large as 5 mm. The liquid retention values as high as 80 ml per 6.45 cm are predicted for some conditions in the range simulated for the mathematical model (i.e. groove depths of 125 ml or less), far above the expected liquid retention on a flat vertical plate without the capillary features. Liquid uptake is, in general, higher as groove depth and contact angle are increased (although as the contact angle approaches 90 degrees and higher, the capillary features may be more difficult to wet to fill the grooves initially). As groove width is increased near or beyond 5 mm, the forces created by the large capillary features will be overcome by gravitational effects and the liquid retention in the capillary features will drop significantly.

[0239] Capillary Features in Microchannel Walls

[0240] Capillary features when placed within the wall of a microchannel or protruding above the walls are useful for chemical unit operations (including for reactors, separators, and heat exchangers) to enable the selective retention of a liquid on or near the microchannel wall. The features may be of any shape (rectangular, circular, trapezoidal, other) as long as they provide at least one critical dimension less than a defined parameter based on the fluid properties such that capillary forces are stronger than gravitational forces to prevent draining or slip along the microchannel walls.

[0241] Capillary features protruding from the average surface of a microchannel wall are preferably formed of the same material as the plate which forms the microchannel wall. The capillary features could be formed as through slots or holes in a thin metal shim that is stacked adjacent to a wall shim prior to diffusion bonding. The resulting structure would be similar to recessed features in the first microchannel wall.

[0242] Capillary features may be placed along the length of the microchannel at the desired location to create a uniform or tailored intrachannel distribution. To promote good channel-to-channel uniformity, the same profile of capillary features are placed along every parallel microchannel in an array of microchannels. The features are preferentially aligned normal to the direction of gravity to minimize draining with the direction of gravity. The features may be aligned at an angle with respect to the direction of gravity during draining. The features may be oriented parallel to the direction of gravity if they are short and discontinuous. On a microchannel wall, there are preferably three, five, ten, or more features in a group.

[0243] In one embodiment a tailored profile may leave more capillary features and thus more catalyst solution near the front of a reactor section where the demand for catalyst is higher. In another embodiment for the case of an exothermic reaction, such as a selective oxidation, the amount of catalyst placed or retained near the front of the reactor may be reduced to in turn reduce the amount of heat released and thus unwanted temperature rise. In a third embodiment, the location and size of capillary features may be tailored on the edge channels of a microchannel device such that the heat release is reduced near the device edge. For example, in a layer of a microchannel device, there may be a higher concentration of capillary features near the center of the layer than near an edge so that more coating is applied near the center of the device. Thus, on a layer comprising an array of microchannels with at least one central microchannel and two edge microchannels, in some embodiments the at least one central channel can have a higher concentration of capillary features than the concentration in either of the two edge channels; this can be reversed if greater catalyst concentration is desired along the edge. This may create an